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(54) METHOD FOR THE MANUFACTURE OF A MEMBRANE-CONTAINING MICROSTRUCTURE

VERFAHREN ZUR HERSTELLUNG EINER MEMBRANHALTENDEN MIKROSTRUKTUR

PROCEDE DE FABRICATION D'UNE MICROSTRUCTURE RENFERMANT UNE MEMBRANE

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Description

[0001] The present invention relates to a novel method for manufacturing a microstructure comprising an elastic membrane.

[0002] WO 90/05295 discloses an optical biosensor system wherein a sample solution containing biomolecules is passed over a sensing surface having immobilized thereon ligands specific for the biomolecules. Binding of the biomolecules to the sensing surface of a sensor chip is detected by surface plasmon resonance spectroscopy (SPRS). A microfluidic system comprising channels and valves supplies a controlled sample flow to the sensor surface, allowing real time kinetic analysis at the sensor surface.

[0003] The microfluidic system is based upon pneumatically controlled valves with a thin elastomer as membrane and comprises two assembled plates, e.g. of plastic, one of the plates having fluid channels formed by high precision moulding in an elastomer layer, such as silicone rubber, applied to one face thereof. The other plate has air channels for pneumatic actuation formed therein which are separated from the fluid channels in the other plate by an elastomer membrane, such as silicone rubber, applied to the plate surface. The integrated valves formed have a low dead volume, low pressure drop and a large opening gap minimizing particle problems. Such a microfluidic system constructed from polystyrene and silicone is included in a commercial biosensor system, BIAcore™, marketed by Pharmacia Biosensor AB, Uppsala, Sweden.

[0004] The method of manufacturing this microfluidic system, based upon high precision moulding, however, on the one hand, puts a limit to the miniaturization degree, and, on the other hand, makes it time-consuming and expensive to change the configuration of the system.

[0005] Elderstig, H., et al., Sensors and Actuators A46: 95-97, 1992 discloses the manufacture of a capacitive pressure sensor by surface micromachining. On a substrate having a silicon oxide layer and a superposed silicon nitride layer, a continuous cavity is etched in the oxide layer through a large amount of small holes in the nitride layer. A polyimide film is then spun on top of the perforated membrane to close the holes.

[0006] The object of the present invention is to provide a method which simplifies the fabrication of and permits further miniaturization of microfluidic structures as well as other structures comprising a flexible polymer membrane.

[0007] According to the present invention this object is achieved by integrating a polymer deposition process into a fabrication sequence which comprises micromachining of etchable substrates.

[0008] In its broadest aspect, the present invention therefore provides a method for the manufacture of a microstructure having a top face and a bottom face, at least one hole or cavity therein extending from the top face to the bottom face, and a polymer membrane which extends over a bottom opening of said hole or cavity, which method comprises the steps defined in claim 1.

[0009] The substrate body is preferably of etchable material and is advantageously plate- or disk-shaped. While silicon is the preferred substrate material, glass or quartz may also be contemplated for the purposes of the invention. The substrate body may also be a composite material, such as a silicon plate covered by one or more layers of another etchable material or materials, e.g. silicon nitride, silicon dioxide etc. Preferred polymer materials are elastomers, such as silicone rubber and polyimide.

[0010] The formation of the holes or cavities is preferably effected by etching, optionally from two sides, but partial or even complete formation of the holes may also be performed by other techniques, such as laser drilling.

[0011] Deposition of the polymer layer may be performed by spin deposition, which is currently preferred, but also other polymer deposition techniques may be contemplated, such as areosol deposition, dip coating etc.

[0012] The application of a membrane support in the form of a sacrificial support layer for the polymer may be required before depositing the polymer, since (i) application of the polymer directly to a completed through-hole or -holes will result in the polymer flowing into and partially filling the hole rather than forming a membrane over it, and (ii) in the case of hole etching, for conventional silicon etching agents, such as KOH and BHF (buffered hydrogen fluoride), a polymer membrane which is applied before the hole etching procedure is completed will lose its adherence to the substrate during the etch. Such a sacrificial support layer may be applied before or after etching the hole or holes.

[0013] When the sacrificial support layer is applied before the hole etch, it may be a layer of a material which is not affected by the hole etch, for example a silicon oxide or nitride layer applied to the hole bottom side of the substrate before the etch. After etching of the hole (s) and deposition of the polymer, the sacrificial layer is then selectively etched away.

[0014] In the case of applying the sacrificial support layer after the formation of the hole or holes, the hole bottom side of the substrate is first covered by a protective layer. In case the hole or holes are formed by etching, such a protective layer may be a layer of a material which is not affected by the hole etch, such as, for example, a silicon oxide or nitride layer, thereby leaving the etched hole or holes covered by this protective layer. A selectively removable sacrificial support layer, such as a photoresist, is then applied to the open hole side of the substrate, thereby filling the bottom of the holes, whereupon the protective layer is removed and the polymer layer is deposited against the bared substrate face including the filled hole bottom(s). The support layer can then be removed without affecting the adherence of the elastomer layer to the substrate.

[0015] By combining polymer spin deposition methods with semiconductor manufacturing technology as described above, a wide variety of polymer membrane-containing microstructures may be conveniently produced, such as for example, valves, pressure sensors, pumps, semipermeable sensor membranes, etc.

[0016] In the following, the invention will be described in more detail with regard to some specific non-limiting embodiments, reference being made to the accompanying drawings, wherein:

Fig. 1 is a schematic exploded sectional view of one embodiment of a membrane valve;
Figs. 2A to 2F are schematic sectional views of a processed silicon substrate at different stages in one process embodiment for the production of a part of the membrane valve in Fig. 1;
Figs. 3A to 3D are schematic partial sectional views of a processed silicon substrate at different stages in a process embodiment for the production of a membrane valve member with a securing groove for the membrane;
Figs. 4A to 4F are schematic partial sectional views of a processed silicon substrate at different stages in an alternative process embodiment for the production of the membrane valve member in Fig. 1;
Figs. 5A and 5B are schematic partial sectional views of a one-way valve; and
Figs. 6A and 6B are schematic partial sectional views of a membrane pump.

[0017] The chemical methods to which it will be referred to below are well-known from inter alia the manufacture of integrated circuits (IC) and will therefore not be described in further detail. It may, however, be mentioned that two basal etching phenomenons are used in micromachining, i.e. that (i) depending on substrate and etching agent, the etch may be dependent on the crystal direction or not, and (ii) the etch may be selective with regard to a specific material.

[0018] In a crystal direction dependent etch in a crystalline material, so-called anisotropic etch, etching is effected up to an atomic plane (111), which gives an extremely smooth surface. In a so-called isotropic etch, on the other hand, the etch is independent of the crystal direction.

[0019] The above-mentioned selectivity is based upon differences in the etch rates between different materials for a particular etching agent. Thus, for the two materials silicon and silicon dioxide, for example, etching with hydrogen fluoride takes place (isotropically) about 1,000 to about 10,000 times faster in silicon dioxide than in silicon. Inversely, sodium hydroxide gives an anisotropic etch of silicon that is about 100 times more efficient than for silicon dioxide, while a mixture of hydrogen fluoride and nitric acid gives a selective isotropic etch of silicon that is about 10 times faster than in silicon dioxide.

[0020] Now with reference to the Figures, Fig. 1 illustrates a membrane valve consisting of three stacked silicon wafers, i.e. an upper silicon wafer 1, a middle silicon wafer 2 and a lower silicon wafer 3.

[0021] The lower wafer 3 has a fluid inlet 4 and a fluid outlet 5 connected via a fluid channel 6 with two valve seats 7 interrupting the flow. The fluid channel 6 may, for example, have a width of about 200 μm and a depth of about 50 μm, and the valve seats 7 may have length of about 10 μm.

[0022] The middle wafer 2 covers the fluid channel and has an elastomer layer 8, e.g. silicone rubber, applied to its underside. Right above each valve seat 7, the silicone layer extends over a hole or recess 9 in the wafer such that a free membrane 8a is formed above each valve seat. Recesses 9 are connected via a channel 10.

[0023] The upper wafer 1, which also has an elastomer layer 11, e.g. silicone rubber, applied to its underside, functions as a lid and has a bore 12 for connection to an air pressure control means.

[0024] It is readily seen that by controlling the air pressure in the channel 10 of the middle wafer 2, and thereby actuating the elastomer membranes 8a above the valve seats 7, the flow through the valve may be accurately controlled.

[0025] A process sequence for manufacturing the middle wafer 2 is shown in Figs. 2A to 2F.

[0026] With reference first to Fig. 2A, a double-polished silicon wafer 2 is oxidized to form an oxide layer 13 thereon. After patterning the air channel 10 (Fig. 1), the oxide layer is etched.

[0027] Silicon nitride deposition is then performed to form a nitride layer 14 as illustrated in Fig. 2B. The membrane holes 9 (Fig. 1) are patterned and the nitride layer 14 is etched to form a nitride mask with the desired hole pattern.

[0028] A deep anisotropic silicon etch is then effected, e.g. with KOH (30%), through the nitride mask, resulting in partial membrane holes 9', as shown in Fig. 2C.

[0029] After a selective etch of the nitride mask 14, a selective silicon etch is performed, e.g. with KOH-IPA, to complete the opening of the membrane holes 9 and simultaneously etch the air channel 10. The resulting wafer with only the thin oxide/nitride layers 13, 14 covering the membrane holes 9 is illustrated in Fig. 2D.

[0030] With reference now to Fig. 2E, the remaining nitride layer 14 on the sides and bottom of the wafer 2 is then selectively etched, and a thin layer, for example about 25 μm thickness, of an elastomer, e.g. a two-component silicone elastomer 15, is applied by spin-deposition.

[0031] Finally, the bared oxide 13 at the bottom of holes 9 is selectively etched by an agent that does not affect the elastomer 15, such as an RIE plasma etch. The completed middle wafer 2 is shown in Fig. 2F.

[0032] The upper silicon wafer 1 of the valve in Fig. 1 is produced by spin deposition of the elastomer layer 11

to a silicon wafer, and laser boring of the hole 12.

[0033] The lower silicon wafer 3 of the valve is prepared by first oxidizing a silicon wafer, patterning the fluid channel 6, and etching the patterned oxide layer to form an oxide mask with the desired channel pattern. A selective silicon etch is then performed through the oxide mask, e.g. with KOH-IPA, to form the fluid channel 6. After laser drilling of the fluid inlet and outlet holes 4 and 5, fluid channel 6 is oxidized.

[0034] The valve is completed by assembly of the three wafers 1-3 and mounting thereof in a holder (not shown).

[0035] It is readily seen that a plurality of such valves may be provided in a single silicon wafer. The number of valves that may be contained in the wafer, i.e. the packing degree, for the above described silicon etching procedures is mainly determined by the thickness of the wafer (due to the tapering configuration of the etched holes). For example, with a 200 μm thick silicon wafer, each valve would occupy an area of at least 0.5 x 0.5 mm, permitting a packing of up to about 280 valves/cm^2.

[0036] In the case of the silicon being etched with RIE, however, completely vertical hole sides may be obtained, permitting a packing degree of about 1000 valves/cm^2 for 200 x 200 μm membranes.

[0037] If desired, the attachment of the elastomer membrane to the substrate in the valve area may be improved by providing a fixing groove for the membrane in the substrate surface, as illustrated in Figs. 3A to 3D.

[0038] Fig. 3A shows a silicon wafer 16 with an oxide layer 17 forming a sacrificial membrane 17a over a valve through-hole 18 in the wafer 16. An annular edge attachment, or fixing groove, is patterned on the oxide layer 17 around the opening 18, whereupon the bared oxide parts are etched away.

[0039] The silicon is then dry-etched at 19a to a depth of, say, about 10 μm, as illustrated in Fig. 3B. By then subjecting the silicon to an anisotropic KOH etch to a depth of about 10 μm, negative sides of the etched groove may be obtained.

[0040] Fig. 3C shows the completed groove 19, which has a width of about twice the depth. An elastomer membrane 20, such as silicone rubber, is then spin deposited onto the substrate surface. A first deposition at a high rotation speed provides for good filling of the groove 19, and a subsequent deposition at a low rotation speed gives a smooth surface. The sacrificial oxide membrane is then etched away as described previously in connection with Figs. 2A to 2F.

[0041] Figs. 4A to 4F illustrate an alternative way of providing a sacrificial membrane for initially supporting the elastomer membrane.

[0042] A silicon wafer 21 is coated with an oxide layer 22 and a superposed nitride layer 23, as shown in Fig. 4A.

[0043] A hole 24 is then opened in the upper oxide/nitride layers and the silicon wafer is etched straight through down to the oxide, as illustrated in Fig. 4B.

[0044] A thick layer of positive photoresist 25 is then spun onto the etched face of the wafer, partially filling the hole 24 as shown in Fig. 4C.

[0045] The lower oxide/nitride layers 22, 23 are subsequently etched away by a dry etch, and the resulting wafer is shown in Fig. 4D.

[0046] An elastomer layer 26, such as silicone rubber, is then spin deposited to the lower face of the wafer to the desired thickness, e.g. about 50 μm, as illustrated in Fig. 4E.

[0047] The positive photoresist 25 is then removed, e.g. with acetone. The completed wafer is shown in Fig. 4F.

[0048] In the embodiments above, sacrificial membranes of oxide and photoresist, respectively, have been described. To improve the strength of the sacrificial membrane, however, a combined oxide/nitride sacrificial membrane may be used, i.e. in the process embodiment described above with reference to Figs. 2A - 2F, the nitride need not be etched away before the elastomer deposition. Alternatively, a sacrificial membrane structure consisting of a polysilicon layer sandwiched between two oxide layers and an outer protective nitride layer may be used. As still another alternative, an etch-resistent metal layer may be used as the sacrificial membrane.

[0049] In a variation of the process embodiments described above with reference to Figs. 2A to 2F and 4A to 4F, respectively, a major part, say about 3/4, of the depth of holes 9 and 24, respectively, may be preformed by laser-drilling from the top face of the chip, only the remaining hole portion then being etched. Not only will such a procedure speed up the manufacturing procedure to a substantial degree, provided that the number of holes per wafer is relatively low (<1000), but will also permit a still higher packing degree.

[0050] A non-return valve produced by the method of the invention is illustrated in Figs. 5A and 5B. The valve consists of two silicon plates 27 and 28. The lower silicon plate 27 has a fluid channel 29 with a valve seat 30 therein. The valve seat 30 includes a free-etched flexible tongue 31. The upper silicon plate 28 has an elastomer membrane 32 extending over an etched trough-hole 33 in the plate and may be produced as described above with regard to Figs. 2A to 2F.

[0051] As is readily understood, a fluid flow from the right is blocked (Fig. 5A), whereas a fluid flow from the left may be made to pass by actuation of the membrane 32.

[0052] Figs. 6A and 6B show a membrane pump produced utilizing the method of the invention. The pump consists of a lower silicon plate 34 having a fluid channel 35 with two valve seats 36 and 37 therein, and an upper silicon plate 38, produced as described above with reference to Figs. 2A to 2F. The upper plate 38 comprises three silicone membrane-covered through-holes 39, 40 and 41, each connected to a controlled pressurized air source. The membrane-covered holes 39 and 41 are lo-

cated just above the valve seats 36 and 37 to form membrane valves therewith. The third membrane-covered hole 40 is larger and functions as a fluid actuating member.

[0053] It is readily realized that by simultaneously and individually actuating the three membranes of holes 39, 40 and 41 in the directions indicated by the arrows in Fig. 6A, fluid will enter from the left in the figure into the part of fluid channel 35 located between the valve seats 36 and 37. The fluid will then be pressed out to the right by simultaneously and individually actuating the membranes of holes 39, 40 and 41 in the directions indicated by the arrows in Fig. 6B. In this way, an efficient pumping action is obtained.

[0054] The described membrane pump will have a low pressure drop which makes it possible to pump at a high pressure with no leakage in the reverse direction. Since the valves open with a relatively large gap, it will also be possible to pump fairly large particles, which is otherwise a problem with pumps produced by micromachining techniques.

[0055] The invention will now be illustrated further by the following non-limiting Example.

EXAMPLE

[0056] A silicon wafer of 500 μm thickness was processed by the procedure discussed above in connection with Figs. 2A to 2F to produce a number of valve plates for use in a membrane valve of the type shown in Fig. 1 as follows.

<u>Etch of oxide mask for air channel (Fig. 2A)</u>

[0057] The wafer was washed and then oxidized to produce an oxide layer of 1.5 μm. A 1.2 μm photoresist layer was then applied to the top face of the wafer, soft-baked for 60 seconds and patterned with a mask corresponding to the desired air channel. The photoresist was then spray developed and hard-baked for 15 min at 110 °C. The back-side of the wafer was then coated with a 1.5 μm photoresist layer and hard-baked at 110 °C for 10 min. The 1.5 μm oxide layer was wet-etched by BHF (ammonium buffered hydrogen fluoride), whereupon the photoresist was stripped off.

<u>Etch of nitride mask for membrane holes (Fig. 2B)</u>

[0058] Nitride was then deposited to form a 1500 Å nitride layer. A 1.5 μm photoresist layer was applied to the nitride layer, soft-baked and patterned with a mask corresponding to the membrane holes. The photoresist was spray developed and hard-baked at 110 °C for 20 min. The back-side of the wafer was then coated with a 1.5 μm photoresist layer and hard-baked at 110 °C for 10 min.

[0059] The bared nitride portions were then dry-etched by RIE (Reactive Ion Etch) down to the silicon substrate, whereupon the photoresist was dry-stripped with an oxygen plasma at 120 °C.

<u>Initial etch of membrane holes (Fig. 2C)</u>

[0060] After a short oxide etch with hydrogen fluoride 1:10 for 10 seconds, a silicon etch was performed with 30% KOH to a depth of about 420 μm (etch rate about 1.4 μm/min).

<u>Etch of air channel and membrane holes (Fig. 2D)</u>

[0061] 1.5 μm photoresist was applied to the back-side of the wafer and hard-baked at 110 °C for 30 min. The remaining front nitride layer was then dry-etched by RIE, followed by dry-stripping of the photoresist with an oxygen plasma at 120 °C. A short oxide etch with hydrogen fluoride 1:10 for 10 seconds was performed, immediately followed by a silicon etch with KOH/propanol (2 kg KOH, 6.5 l H_2O, 1.5 l propanol) at 80 °C to a depth of about 100 μm (etch rate about 1.1 μm/min) i.e. down to the oxide layer on the back-side of the wafer.

<u>Deposition of silicone membrane (Fig. 2E)</u>

[0062] The nitride on the back-side of the silicon wafer was then etched away, followed by oxidation to 1.5 μm. After drying at 180 °C for 30 min, a 20 μm layer of a two-component silicone rubber was applied to the oxide layer on the back-side of the wafer by spin-deposition at 2000 rpm for 40 seconds and then cured at 100 °C for 30 min to form a silicone membrane.

<u>Etch of sacrificial oxide membrane (Fig. 2F)</u>

[0063] The oxide layer on the back-side of the wafer was removed by a dry oxide etch through the etched holes in the silicon to bare the silicone membrane.

[0064] The silicon wafer was finally divided into separate valve plates by sawing.

[0065] The invention is, of course, not restricted to the embodiments specifically described above and shown in the drawings, but many modifications and changes may be made within the scope of the general inventive concept as defined in the following claims.

Claims

1. A method for the manufacture of a microstructure having a top face and a bottom face, at least one hole or cavity therein extending from the top face to the bottom face, and a polymer membrane which extends over a bottom opening of said hole or cavity, which method comprises the steps of:

    providing a substrate body (2; 21) having said top and bottom faces,

forming said at least one hole or cavity (9; 24) in the substrate body,
providing a membrane support (13; 25) at the bottom face opening of said at least one hole or cavity,
depositing a layer (15; 26) of polymer material onto the bottom face of said substrate body (2; 21) against said membrane support (13; 25),
selectively removing said membrane support (13; 25) to bare said polymer membrane (15; 26) over the bottom opening of the at least one hole or cavity; or which method comprises the steps of:

providing a substrate body (2; 21) having said top and bottom faces,

forming at least part of said at least one hole or cavity (9; 24) in the substrate body,
providing a membrane support (13; 25) at the bottom face opening of said at least one hole or cavity,
depositing a layer (15; 26) of polymer material onto the bottom face of said substrate body (2; 21) against said membrane support (13; 25),
completing the formation of the at least one hole or cavity (9; 24), and
selectively removing said membrane support (13; 25) to bare said polymer membrane (15; 26) over the bottom opening of the at least one hole or cavity.

2. The method according to claim 1, wherein the substrate body (2, 21) is of etchable material.

3. The method according to claim 1 or 2, wherein said membrane support (13; 25) is part of the substrate body (2; 21).

4. The method according to claim 3, wherein the substrate body (2) comprises an outer layer forming said membrane support layer (13) for the polymer membrane, the polymer material (15) is deposited onto said support layer (13), and the support layer is subsequently selectively removed to bare the polymer membrane (8a).

5. The method according to claim 4, which comprises the sequence of applying said membrane support layer (13) to the substrate body (2), etching one or more holes (9) in the substrate body up to the membrane support layer (13), depositing the polymer material (15) onto the support layer (13), and selectively removing the support layer to bare the polymer membrane (8a).

6. The method according to claim 1 or 2, which comprises applying said selectively removable membrane support (25) after forming said hole or cavity (24).

7. The method according to claim 6, which comprises the sequence of providing the substrate body (21) with a protective layer (22, 23) on one face thereof, etching one or more holes (24) from the opposite face of the substrate body up to the protective layer (22, 23), applying said membrane support layer (25) to the etched face of the substrate body, selectively removing the protective layer (22, 23), depositing the polymer material onto the membrane support layer (25), and selectively removing the membrane support layer (25) to bare the polymer membrane (26).

8. The method according to any one of claims 1 to 3, which comprises the sequence of depositing the polymer material onto the support layer, and etching one or more holes in the substrate body up to the polymer material layer.

9. The method according to claim 8, wherein the etching is performed by a dry etch, such as a reactive ion etch.

10. The method according to any one of claims 1 to 9, wherein a part, preferably a major part of said holes or cavities, are preformed by laser drilling.

11. The method according to any one of claims 1 to 10, wherein the material of said substrate body is selected from silicon, glass and quartz.

12. The method according to claim 11, wherein said substrate is a silicon wafer.

13. The method according to any one of claims 1 to 12, wherein said polymer material is an elastomer, preferably a silicone rubber.

14. The method according to any one of claims 2 to 5 and 10 to 13, wherein said membrane support layer (13) is silicon oxide or silicon nitride or a combination thereof.

15. The method according to any one of claims 6, 7 and 10 to 14, wherein said membrane support layer (25) is a photoresist material.

16. The method according to any one of claims 1 to 15, wherein the deposition of said polymer is performed by spin deposition.

17. Use of the method according to any one of claims 1 to 16 for producing a microstructure comprising at least one membrane valve.

Patentansprüche

1. Verfahren zur Herstellung einer Mikrostruktur mit einer Oberseite und einer Bodenseite, mindestens einem Loch oder Hohlraum darin, das oder der sich von der Oberseite zu der Bodenseite erstreckt, und einer Polymermembran, welche sich über eine Bodenöffnung des Lochs oder des Hohlraums erstreckt, wobei das Verfahren die Schritte umfasst:

   - Vorsehen eines Substratkörpers (2; 21) mit der Oberseite und der Bodenseite,
   - Bilden des mindestens einen Lochs oder Hohlraums (9; 24) in dem Substratkörper,
   - Vorsehen eines Membranträgers (13; 25) an der Bodenseitenöffnung des mindestens einen Lochs oder Hohlraums,
   - Abscheiden einer Schicht (15; 16) aus Polymermaterial auf der Bodenseite des Substratkörpers (2; 21) gegen den Membranträger (13; 25),
   - selektives Entfernen des Membranträgers (13; 25), um die Polymermembran (15; 26) über der Bodenöffnung des mindestens einen Lochs oder Hohlraums blank zu legen;

   oder wobei das Verfahren die Schritte umfasst:

   - Vorsehen eines Substratkörpers (2: 21) mit der Oberseite und der Unterseite,
   - Bilden mindestens eines Teils des mindestens einen Lochs oder Hohlraums (9; 24) in dem Substratkörper,
   - Vorsehen eines Membranträgers (13; 25) an der Bodenseitenöffnung des mindestens einen Lochs oder Hohlraums,
   - Abscheiden einer Schicht (15; 26) aus Polymermaterial auf der Bodenseite des Substratkörpers (2; 21) gegen den Membranträger (13; 25),
   - Vervollständigen der Ausbildung des mindestens einen Lochs oder Hohlraums (9: 24), und
   - selektives Entfernen des Membranträgers (13; 25), um die Polymermembran (15; 26) über der Bodenöffnung des mindestens einen Lochs oder Hohlraums blank zu legen.

2. Verfahren nach Anspruch 1, wobei der Substratkörper (2; 21) aus ätzbaren Material besteht.

3. Verfahren nach Anspruch 1 oder 2, wobei der Membranträger (13; 25) Teil des Substratkörpers (2; 21) ist.

4. Verfahren nach Anspruch 3, wobei der Substratkörper (2) eine Außenschicht umfasst, welche die Membranträgerschicht (13) für die Polymermembran bildet, das Polymermaterial (15) auf der Trägerschicht (13) abgeschieden wird, und die Trägerschicht nachfolgend selektiv entfernt wird, um die Polymermembran (8a) blank zu legen.

5. Verfahren nach Anspruch 4, umfassend die Reihenfolge des Aufbringens der Membranträgerschicht (13) auf den Substratkörper (2), Ätzens eines oder mehrerer Löcher (9) in den Substratkörper bis zu der Membranträgerschicht (13), Abscheidens des Polymermaterials (15) auf der Trägerschicht (13) und selektiven Entfernens der Trägerschicht, um die Polymermembran (8a) blank zu legen.

6. Verfahren nach Anspruch 1 oder 2, umfassend das Aufbringen des selektiv entfernbaren Membranträgers (25) nach Bilden des Lochs oder des Hohlraums (24).

7. Verfahren nach Anspruch 6, umfassend die Reihenfolge des Versehens des Substratkörpers (21) mit einer Schutzschicht (22; 23) auf einer Seite hiervon, Ätzens eines oder mehrerer Löcher (24) von der gegenüberliegenden Seite des Substratkörpers bis zu der Schutzschicht (22; 23), Aufbringens der Membranträgerschicht (25) auf die geätzte Seite des Substratkörpers, selektiven Entfernens der Schutzschicht (22; 23), Abscheidens des Polymermaterials auf der Membranträgerschicht (25), und selektiven Entfernens der Membranträgerschicht (25), um die Polymermembran (26) blank zu legen.

8. Verfahren nach mindestens einem der Ansprüche 1 bis 3, umfassend die Reihenfolge des Abscheidens des Polymermaterials auf der Trägerschicht, und des Ätzens eines oder mehrerer Löcher In dem Substratkörper bis zu der Polymermaterialschicht.

9. Verfahren nach Anspruch 8, wobei das Ätzen durch ein Trockenätzen, wie reaktives lonenätzen, durchgeführt wird.

10. Verfahren nach mindestens einem der Ansprüche 1 bis 9, wobei ein Teil, vorzugsweise ein Hauptteil der Löcher oder Hohlräume durch Laserbohren vorgebildet werden.

11. Verfahren nach mindestens einem der Ansprüche 1 bis 10, wobei das Material des Substratkörpers aus Silizium, Glas und Quarz gewählt wird.

12. Verfahren nach Anspruch 11, wobei das Substrat ein Silicumwafer ist.

13. Verfahren nach mindestens einem der Ansprüche 1 bis 12, wobei das Polymermaterial ein Elastomer ist, vorzugsweise ein Siliconkautschuk.

14. Verfahren nach mindestens einem der Ansprüche

2 bis 5 und 10 bis 13, wobei die Membranträgerschicht (13) Siliciumoxid oder Siliciumnitrid oder eine Kombination hiervon ist.

15. Verfahren nach mindestens einem der Ansprüche 6, 7 und 10 bis 14, wobei die Membranträgerschicht (25) ein Fotoresistmaterial ist.

16. Verfahren nach mindestens einem der Ansprüche 1 bis 15, wobei die Abscheidung des Polymeren durch Spinabscheidung durchgeführt wird.

17. Verwendung des Verfahrens gemäß mindestens einem der Ansprüche 1 bis 16 zur Herstellung einer Mikrostruktur, umfassed mindestens ein Membranventil.

Revendications

1. Procédé pour la fabrication d'une microstructure ayant une face supérieure et une face inférieure, au moins un trou ou une cavité s'étendant à l'intérieur depuis la face supérieure jusqu'à la face inférieure, et une membrane polymère qui s'étend sur une ouverture inférieure dudit trou ou de ladite cavité, ledit procédé comportant les étapes consistant à :

> fournir un corps de substrat (2 ; 21) ayant lesdites faces supérieure et inférieure,
> former ledit au moins un trou ou cavité (9 ; 24) dans le corps de substrat,
> agencer une support de membrane (13 ; 25) au niveau de ladite ouverture de face inférieure dudit au moins un trou ou cavité,
> déposer une couche (15 ; 26) d'un matériau polymère sur la face inférieure dudit corps de substrat (2 ; 21) contre ledit support de membrane (13 ; 25),
> éliminer de manière sélective ledit support de membrane (13 ; 25) pour mettre à nu ladite membrane polymère (15 ; 26) sur l'ouverture inférieure du au moins un trou ou cavité, ou lequel procédé comporte les étapes consistant à :
>
> > fournir un corps de substrat (2 ; 21) ayant lesdites faces supérieure et inférieure,
> > former au moins une partie dudit au moins un trou ou cavité (9 ; 24) dans le corps de substrat,
> > agencer un support de membrane (13 ; 25) dans l'ouverture de face inférieure dudit au moins un trou ou cavité,
> > déposer une couche (15 ; 26) d'un matériau polymère sur la face inférieure dudit corps de substrat (2 ; 21) contre ledit support de membrane (13 ; 25),
> > achever la formation du au moins un trou ou cavité (2 ; 24), et
> > éliminer de manière sélective ledit support de membrane (13 ; 25) pour mettre à nu ladite membrane polymère (15 ; 26) sur l'ouverture inférieure du au moins un trou ou cavité.

2. Procédé selon la revendication 1, dans lequel le corps de substrat (2 ; 21) est un matériau pouvant être gravé.

3. Procédé selon la revendication 1 ou 2, dans lequel ledit support de membrane (13 ; 25) est une partie du corps de substrat (2 ; 21).

4. Procédé selon la revendication 3, dans lequel le corps de substrat (2) comporte une couche extérieure formant ladite couche de support de membrane (13) pour la membrane polymère, le matériau polymère (15) est déposé sur ladite couche de support (13), et la couche de support est par la suite éliminée de manière sélective pour mettre à nu la membrane polymère (8a).

5. Procédé selon la revendication 4, qui comporte la séquence consistant à appliquer ladite couche de support de membrane (13) sur le corps de substrat (2), graver un ou plusieurs trous (9) dans le corps de substrat jusqu'à la couche de support de membrane (13), déposer le matériau polymère (15) sur la couche de support (13), et éliminer de manière sélective la couche de support pour mettre à nu la membrane polymère (8a).

6. Procédé selon la revendication 1 ou 2, qui comporte l'application dudit support de membrane (25) pouvant être éliminé de manière sélective, après formation dudit trou ou cavité (24).

7. Procédé selon la revendication 6, qui comporte la séquence consistant à munir le corps de substrat (21) d'une couche protectrice (22, 23) sur une face de celui-ci, graver un ou plusieurs trous (24) depuis la face opposée du corps de substrat jusqu'à la couche protectrice (22, 23), appliquer ladite couche de support de membrane (25) sur la face gravée du corps de substrat, éliminer de manière sélective la couche protectrice (22, 23), déposer le matériau polymère sur la couche de support de membrane (25), et éliminer de manière sélective la couche de support de membrane (25) pour mettre à nu la membrane polymère (26).

8. Procédé selon l'une quelconque des revendications 1 à 3, qui comporte la séquence consistant à déposer le matériau polymère sur la couche de support, et à graver un ou plusieurs trous dans le corps de

substrat jusqu'à la couche de matériau polymère.

9. Procédé selon la revendication 8, dans lequel la gravure est effectuée par une gravure à sec, telle qu'une gravure à ions réactifs.

10. Procédé selon l'une quelconque des revendications 1 à 9, dans lequel une partie, de préférence une partie majeure desdits trous ou cavités, est préformée par perçage laser.

11. Procédé selon l'une quelconque des revendications 1 à 10, dans lequel le matériau dudit corps de substrat est sélectionné parmi du silicium, du verre et du quartz.

12. Procédé selon la revendication 11, dans lequel ledit substrat est une tranche de silicium.

13. Procédé selon l'une quelconque des revendications 1 à 12, dans lequel ledit matériau polymère est un élastomère, de préférence un caoutchouc silicone.

14. Procédé selon l'une quelconque des revendications 2 à 5 et 10 à 13, dans lequel ladite couche de support de membrane (13) est de l'oxyde de silicium ou du nitrure de silicium ou une combinaison de ceux-ci.

15. Procédé selon l'une quelconque des revendications 6, 7 et 10 à 14, dans lequel ladite couche de support de membrane (25) est un matériau de réserve photosensible.

16. Procédé selon l'une quelconque des revendications 1 à 15, dans lequel le dépôt dudit polymère est effectué par dépôt par centrifugation.

17. Utilisation du procédé selon l'une quelconque des revendications 1 à 16 pour produire une microstructure comportant au moins un clapet à membrane.

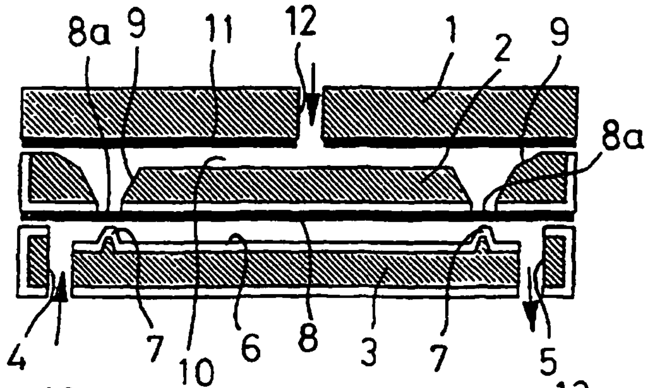

FIG. 1

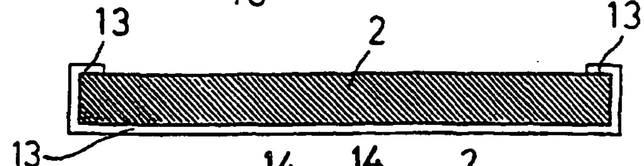

FIG. 2A

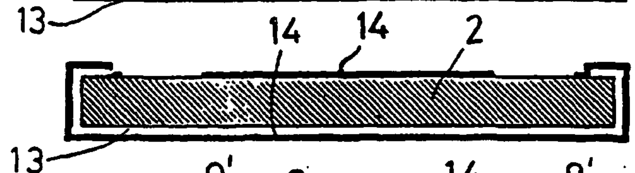

FIG. 2B

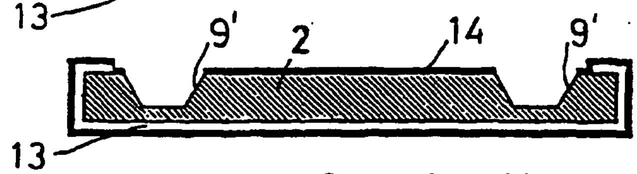

FIG. 2C

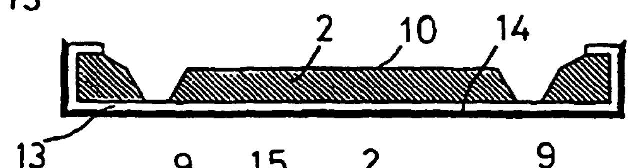

FIG. 2D

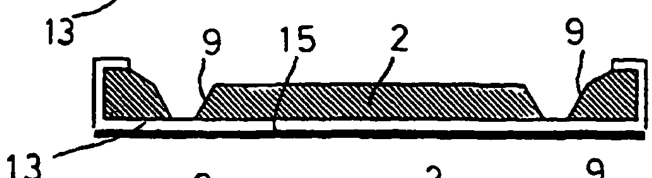

FIG. 2E

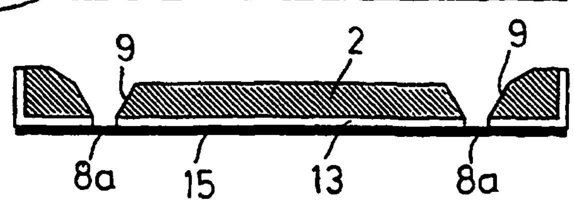

FIG. 2F

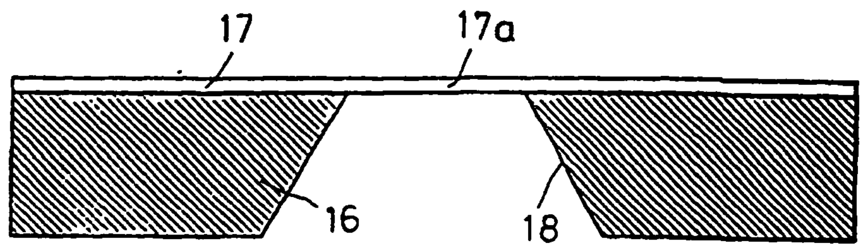

FIG. 3A

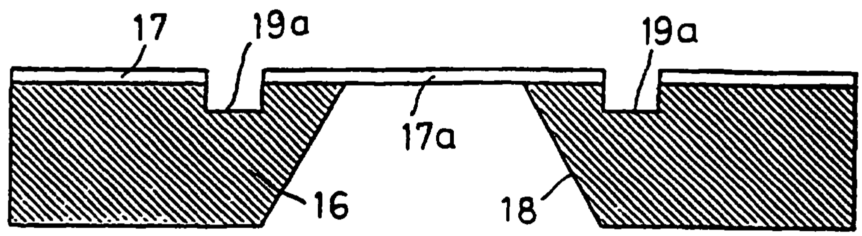

FIG. 3B

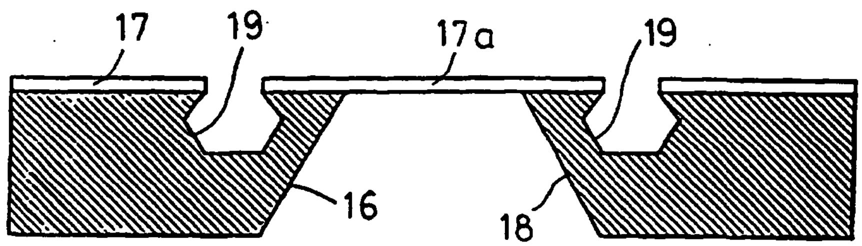

FIG. 3C

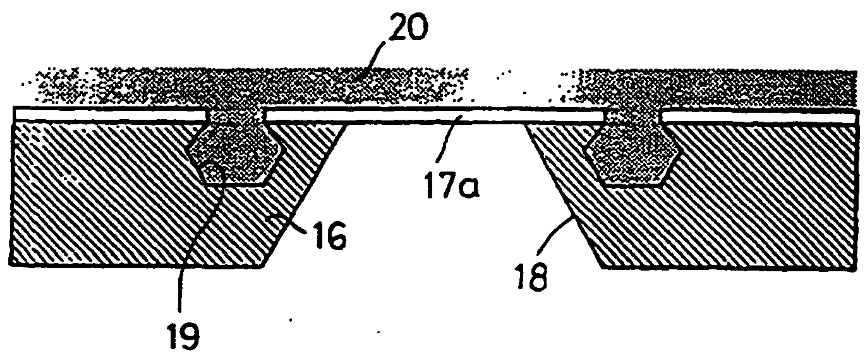

FIG. 3D

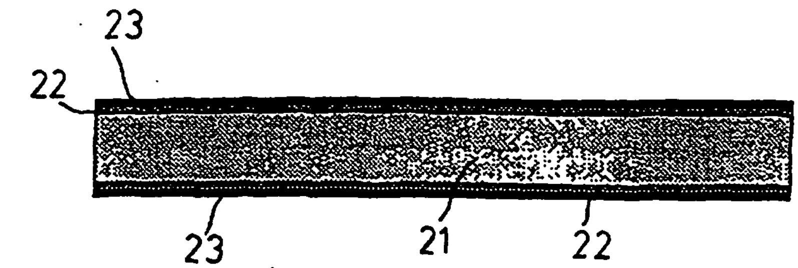

FIG. 4A

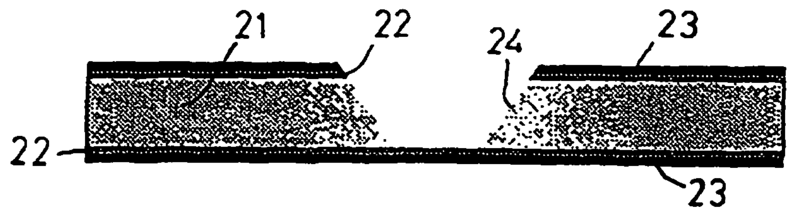

FIG. 4B

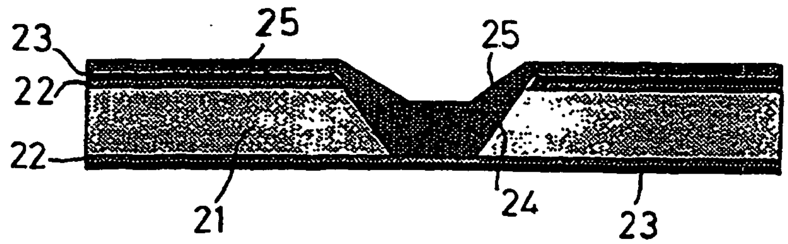

FIG. 4C

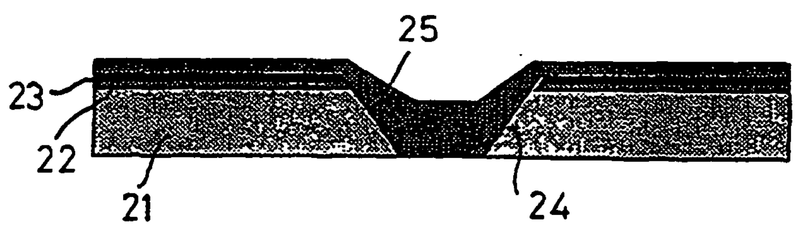

FIG. 4D

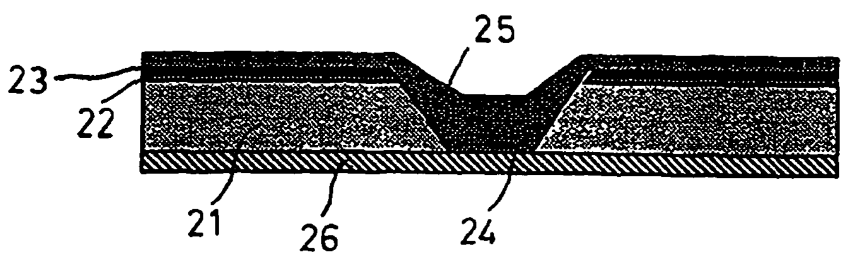

FIG. 4E

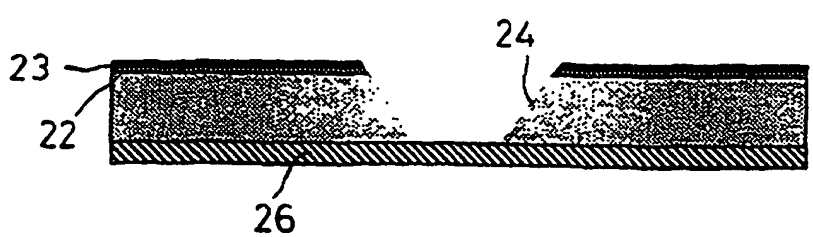

FIG. 4F

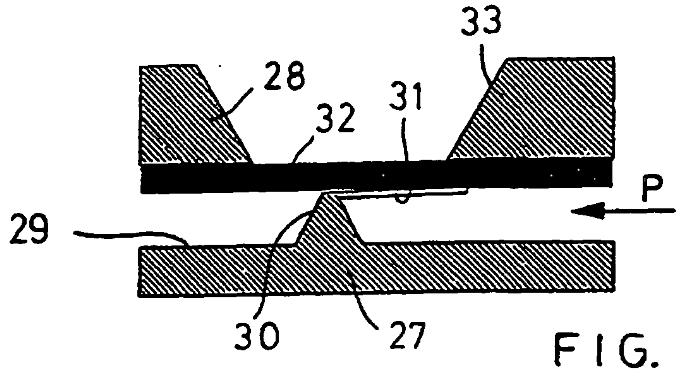

FIG. 5A

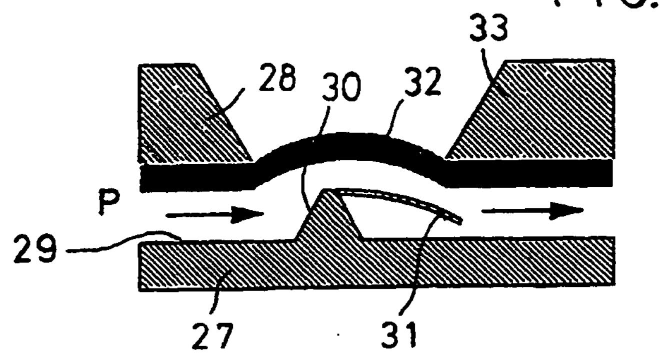

FIG. 5B

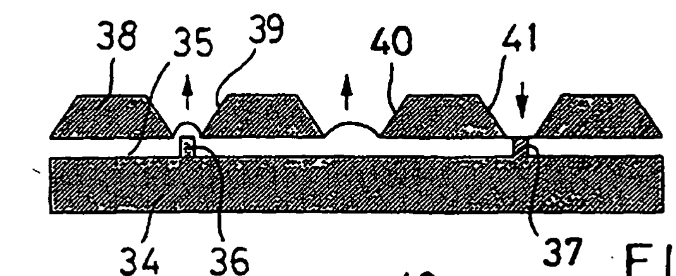

FIG. 6A

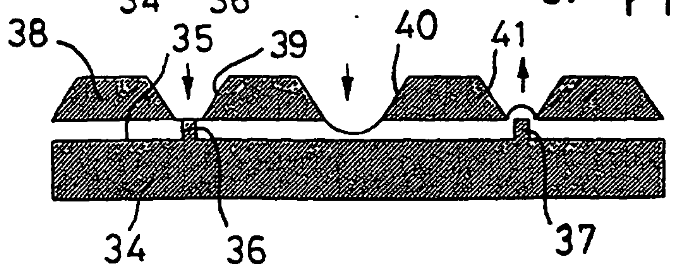

FIG. 6B